Pluto-Kuiper Express: To Our Last Planet and Beyond

Presented at
Pluto and Triton: Comparisons and Evolution Over Time

Lowell Observatory
Flagstaff, Arizona

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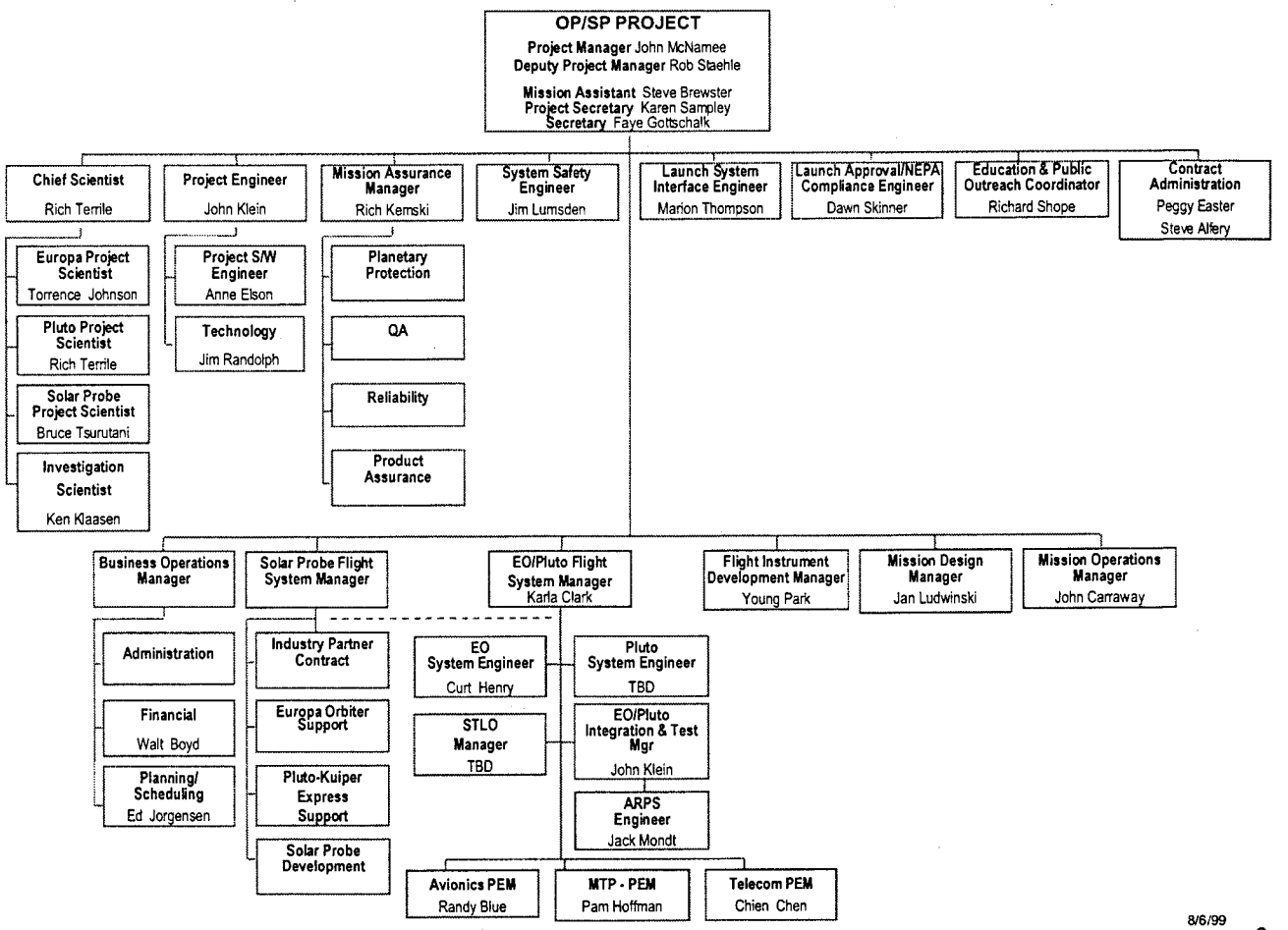
Jet Propulsion Laboratory/California Institute of Technology

Composite art generated from David Seal's Solar System Simulator
http://space.jpl.nasa.gov/



EXPLORATION OF THE SOLAR SYSTEM

Outer Planets/Solar Probe

Key Events

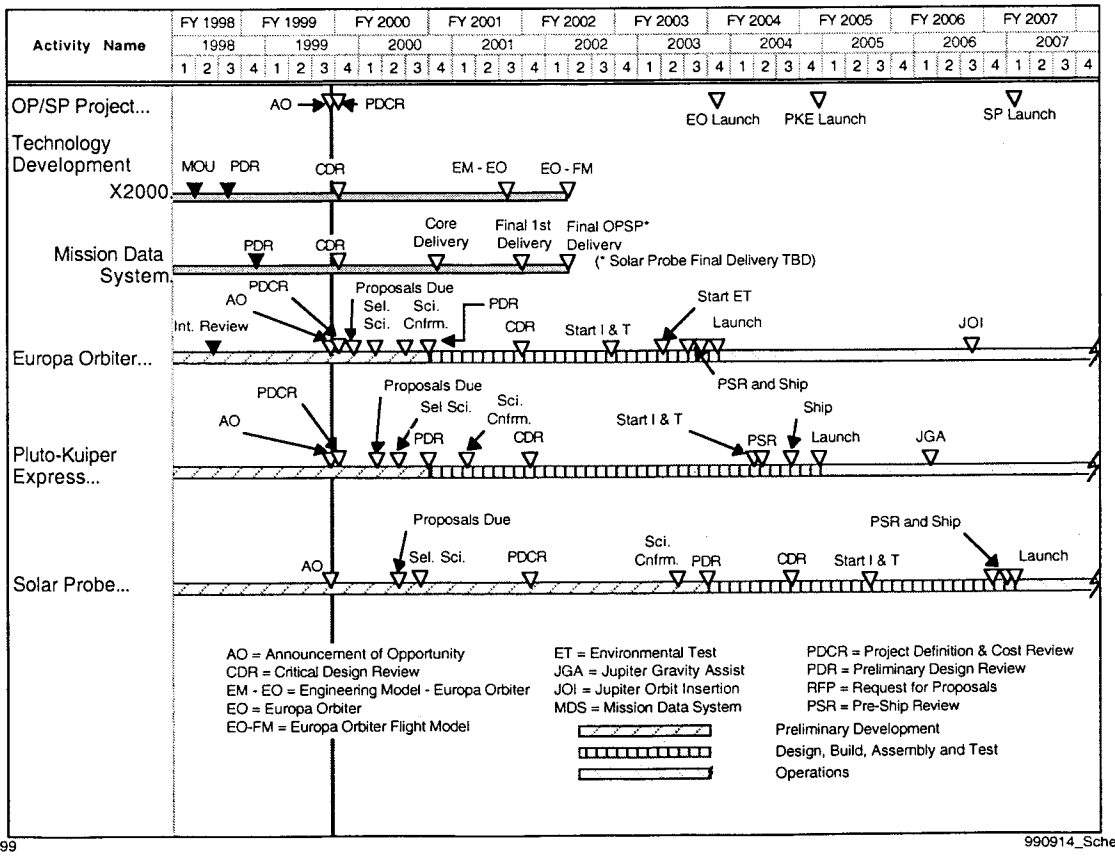
Option	Calendar Year 03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
Europa (Direct)	▼ Nov			▲ JOI Aug		▲ Europa Arrival Apr-Oct									
Pluto (JGA)		▼ Dec		▲ JGA Mar						▲ Encounter					
Solar Probe (JGA)					▼ Feb	▲ JGA Jun		▲ Perihelion Oct		▲ Aphelion Nov			▲ Perihelion Jan		

▼ Launch

▲ Arrival (unless otherwise indicated)

* Europa arrival sensitive to trajectory design and launch date

Outer Planets/Solar Probe Project Preliminary Schedule



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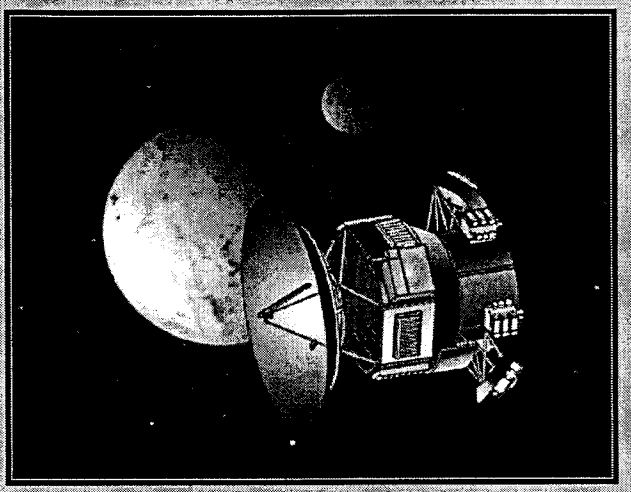
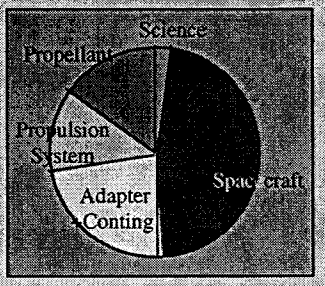
PLUTO-KUIPER EXPRESS



STRAWMAN INVESTIGATIONS

- Imaging
- IR Mapping Spectrometry
- UV Spectrometry
- Radio Science Uplink Occultation



Injected Mass = ~400-450 kg.

C_3 = ~143 km²/sec²

Mission Summary

Trajectory Type	Jupiter Gravity Assist
Launch Date	Dec 2004
Flight Time	8-10 yrs
Launch System	Atlas V or Delta IV/ Star 48

Outer Planets/Solar Probe

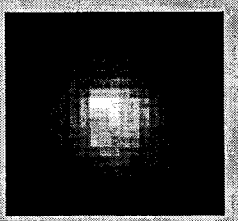
PLUTO-KUIPER EXPRESS

Completing the reconnaissance of the solar system

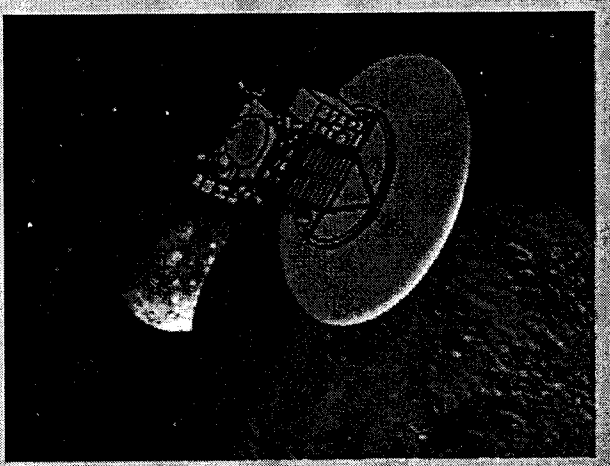
Pluto and the distant objects contain some of the original building blocks of the solar system

EXPLORATION OF THE SOLAR SYSTEM

Objectives:
- Geology of Pluto and Charon
- Maps of surface composition and atmospheric structure
- First images of Kuiper objects



Best image of Pluto to date



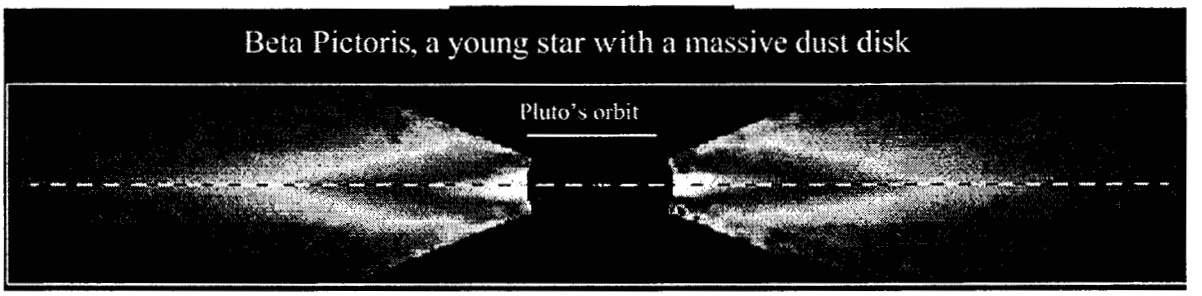
EXPLORATION OF THE SOLAR SYSTEM

The nature and composition of the primordial Kuiper Belt has emerged as a key objective in understanding solar system evolution and the development of life

Pluto/Kuiper Express Science Objectives

- Origins of Pluto, Triton, and the Kuiper Belt
  - Surface volatile distributions
  - Gravitational data to determine water-to-rock ratio
- Atmospheres of Pluto and Charon
  - Determine thermal structure, processes of atmospheric collapse, long-term evolution
- Mass of the primordial Kuiper Belt
  - High-resolution imaging of Pluto, Charon, and a KBO can determine cratering rates and thus population density within the Kuiper Belt

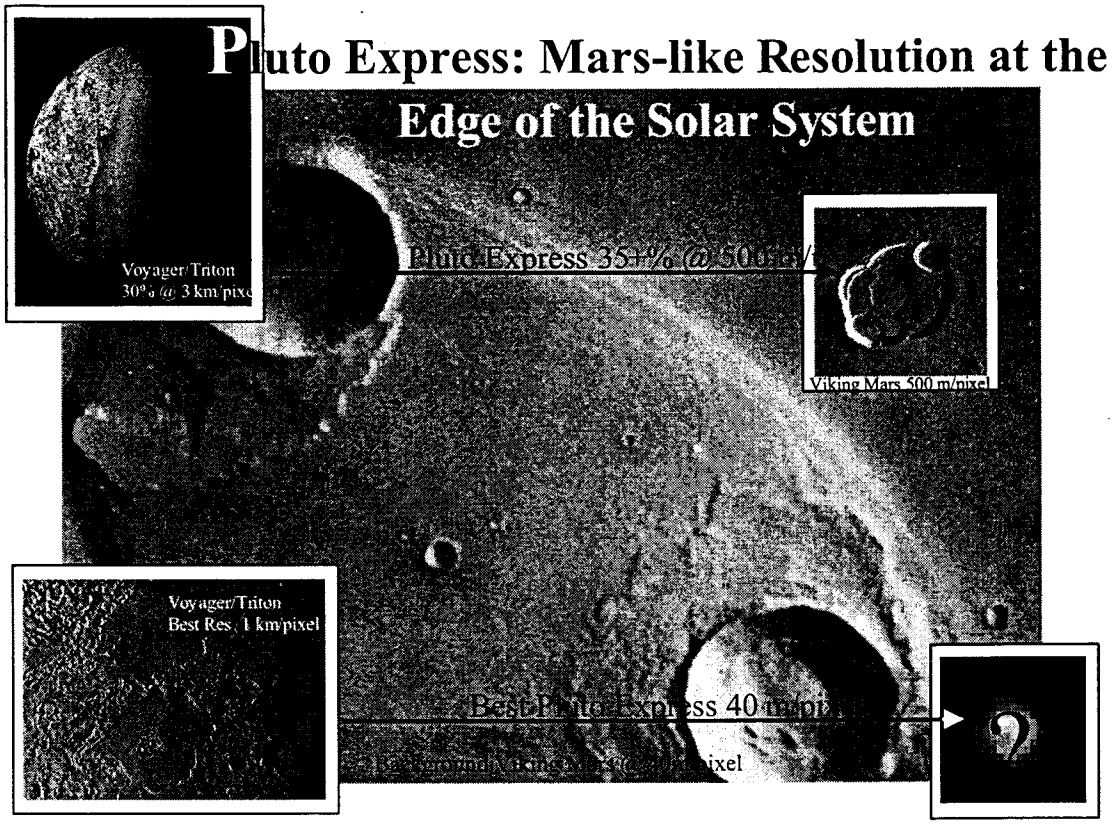
Exploring the Kuiper Belt: Missions to Pluto and Comets



- Pluto/Kuiper Express will look for evidence of a massive primordial Kuiper Belt and characterize bodies in the realm beyond Neptune...

...while future comet missions will directly sample material from the Kuiper Belt.

Pluto Express: Mars-like Resolution at the Edge of the Solar System



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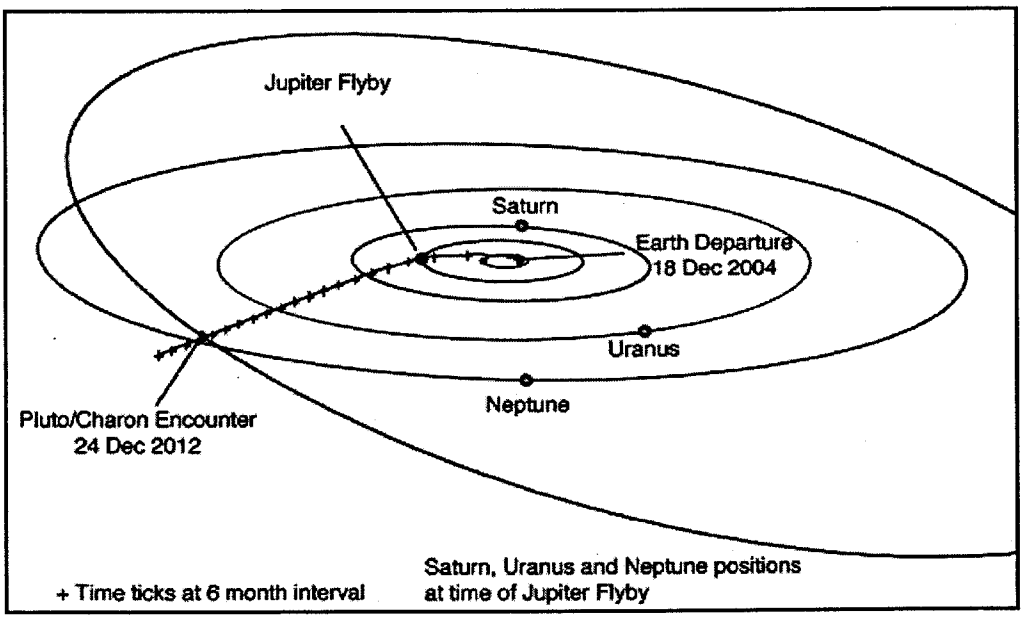
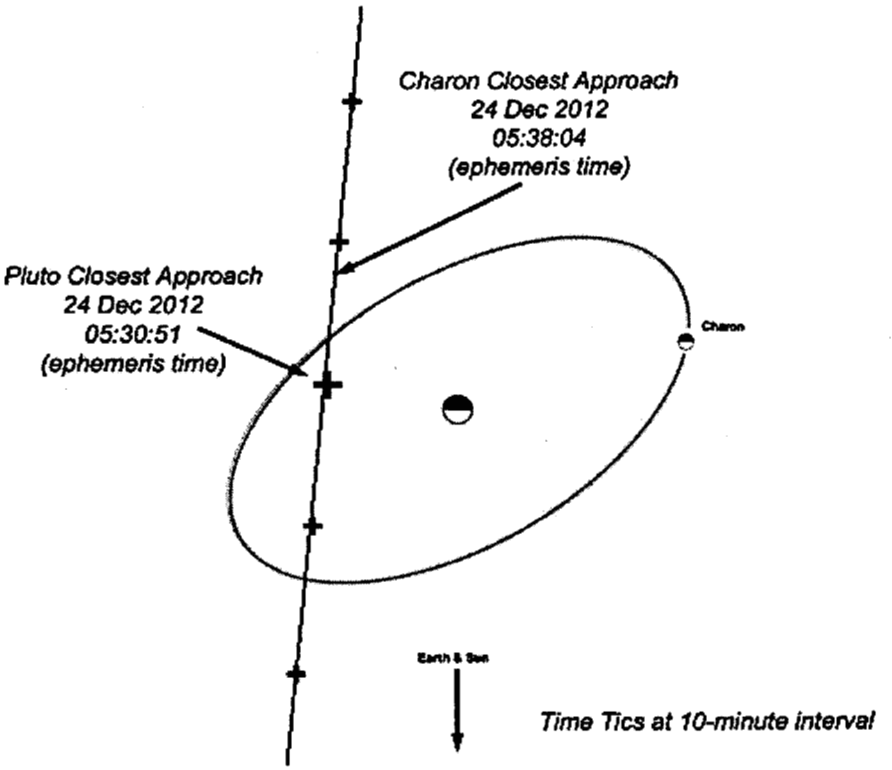




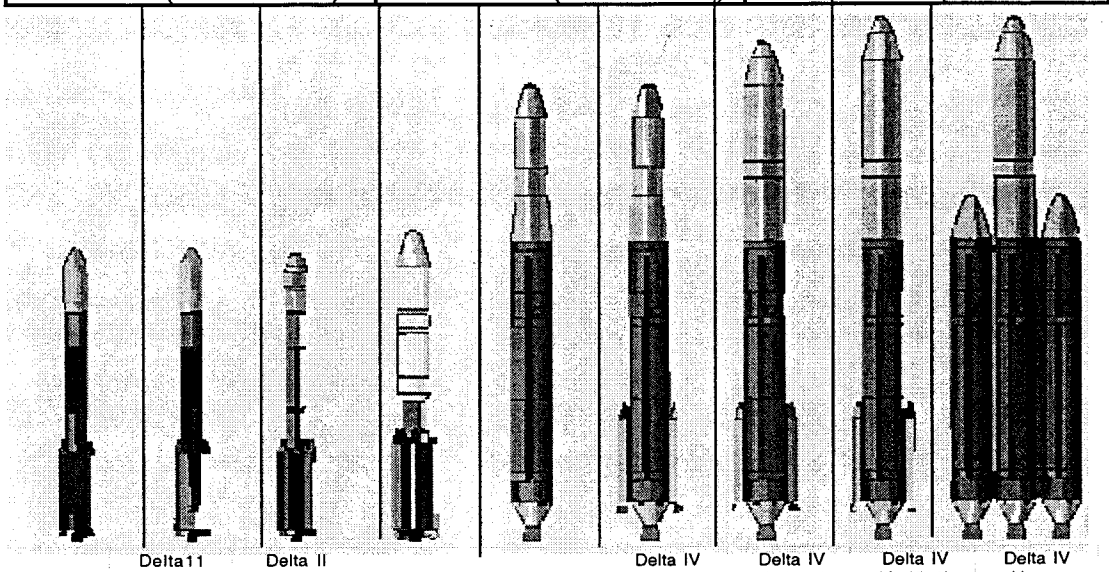
Launch Services

- Launch services for the OP/SP project will include the following:
  - Launch Vehicle
  - Mission Unique Hardware and Services
  - Range Services
  - Payload Processing and Facility Services
- Launch Services competitive procurement is planned as a part of the IDIQ portion of the NASA Launch Services contract on the following schedule:
- OPSP RFP release - 1/01, contract selection 4/01
  - Europa Orbiter Authority to Proceed (ATP) - 4/01
  - Pluto Kuiper Express - ATP - 6/02
  - Solar Probe - ATP - 8/04
- Basic assumption is to procure the same EELV launch vehicle for all three missions in order to save cost (common hardware interface, personnel, procedures and Launch Approval process)

Delta Launch Vehicle Family

Fairing Size	10 feet (3 meters)			13 feet (4 meters)			16.7 feet (5 meters)		

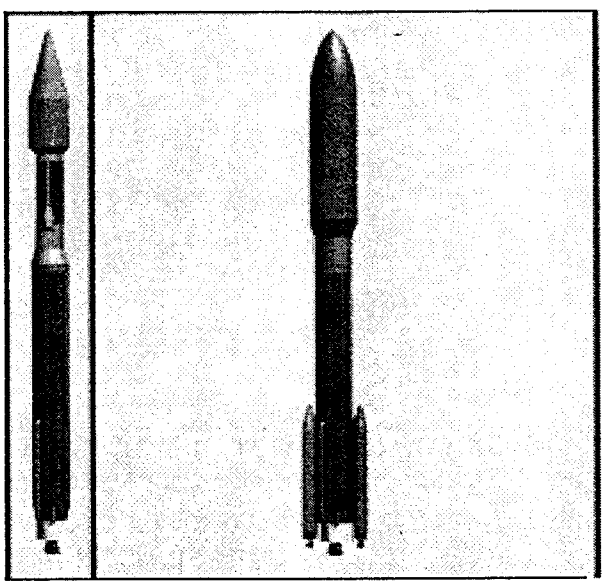
Vehicles



C_3=0 Km²/sec²	Delta II	Delta11 (7425)	Delta II 7925	Delta III	Delta IV	Delta IV M+ (4,2)	Delta IV M+(5,2)	Delta IV M+(5,4)	Delta IV Heavy
	603 kg	785kg	1243kg	2639kg	2731kg	3869kg	2803kg	4180kg	9340kg
C_3=14 Km²/sec²	431	576kg	925kg	2054kg	1930kg	2850kg	1940kg	3149kg	7304kg

First Launch 2001

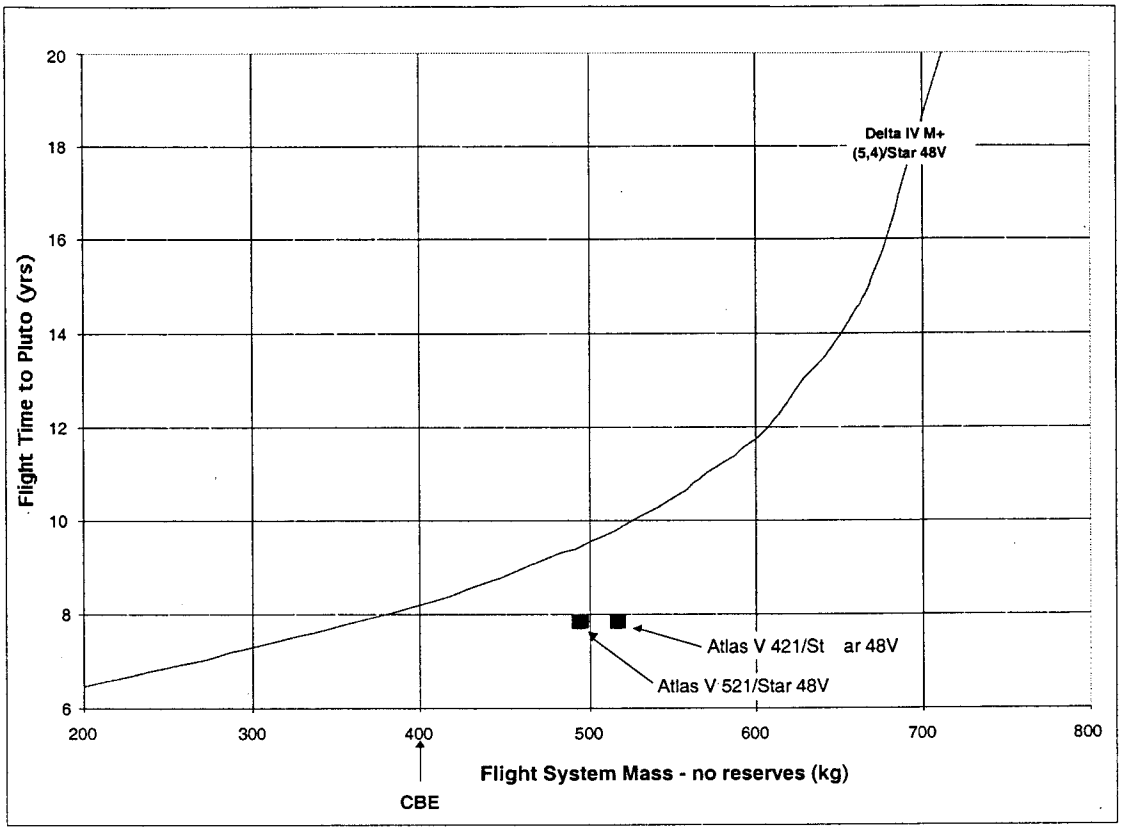
ATLAS V



Atlas V 400	Atlas V 500					
401	501	511	521	531	541	551
Performance to GTO, kg (lb)						
5,000 (11000)	4,100 (9,000)	4,900 (10,800)	6,000 (13,200)	6,900 (15,200)	7,600 16,700)	8,200 (18,000)

First Launch 2001

Pluto Flight Time vs. Flight System Mass For 2004 JGA



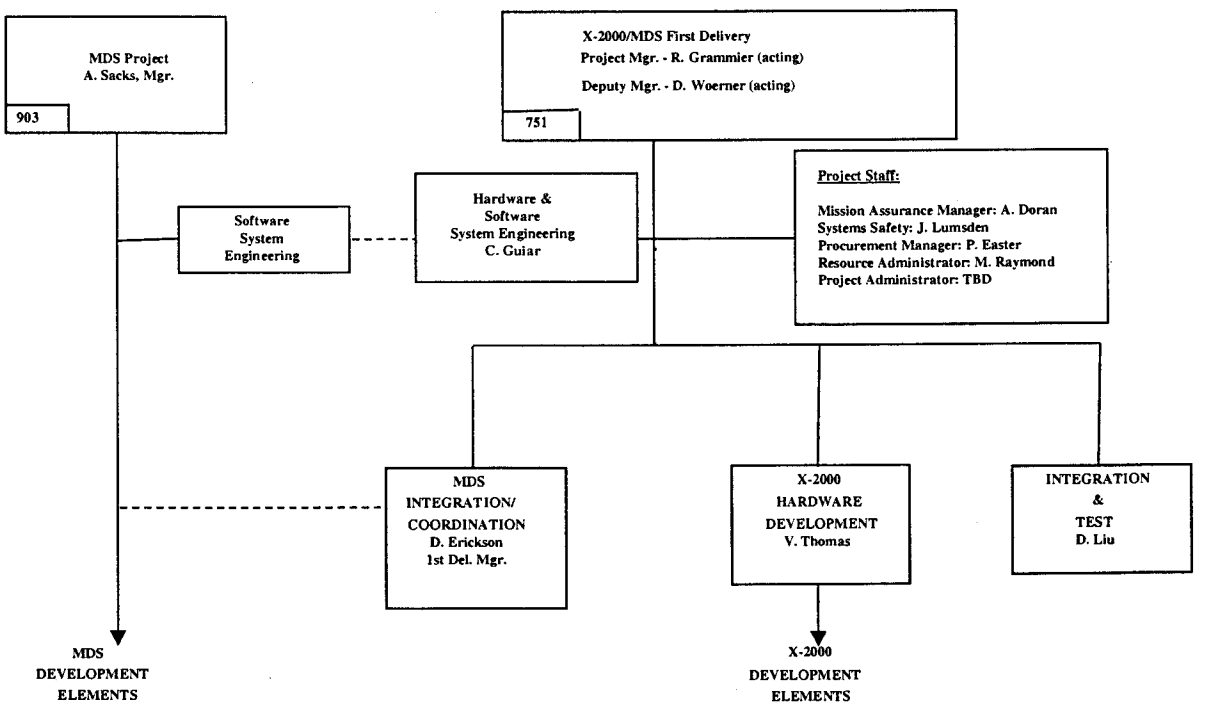
Pluto Flight Driving Requirements

- Fit the budget
  - including low cost flight operations
  - find common design solutions for Europa and Pluto
- Launch in 2004
- *Get to Pluto (and Kuiper Object) and return data*
  - *8 to 14 year lifetime (<10 years to Pluto)*
  - *30 to 35 AU range to Earth*
- *Collect principal science +/- 4 hours of closest approach*
  - *memory sizing*
  - data bus bandwidth
  - *"fine" articulation requirements (mosaics)*
- *Observe Charon*
  - *"coarse" articulation requirements (turns)*
- Fit onto an "affordable" expendable launch vehicle
  - < TBD (450 kg) injected mass
  - environments
- Operate with </= 200 W steady state power at Pluto
- "Don't fail."*Italics represents changes from EO requirements*

System Architecture

- 3 Flight Systems
  - Europa Orbiter
  - Pluto/Kuiper Express Spacecraft
  - Solar Probe
- Common Mission Software System
  - Inherited from Mission Data System Project
  - Adapted and Extended to meet mission unique software needs
- Shared Ground System
  - Operations Control Center
  - Deep Space Network
- 3 Launch Systems
  - TBD Expendable Launch Vehicle for Europa
  - Same Expendable Launch Vehicle for Pluto
  - Same Expendable Launch Vehicle for Solar Probe
  - All 3 Use Star 48V solid rocket motors for interplanetary injection
- 2 Test Systems
  - Shared system for Europa & Pluto
  - Separate system for Solar Probe (with much inheritance from Europa/Pluto)

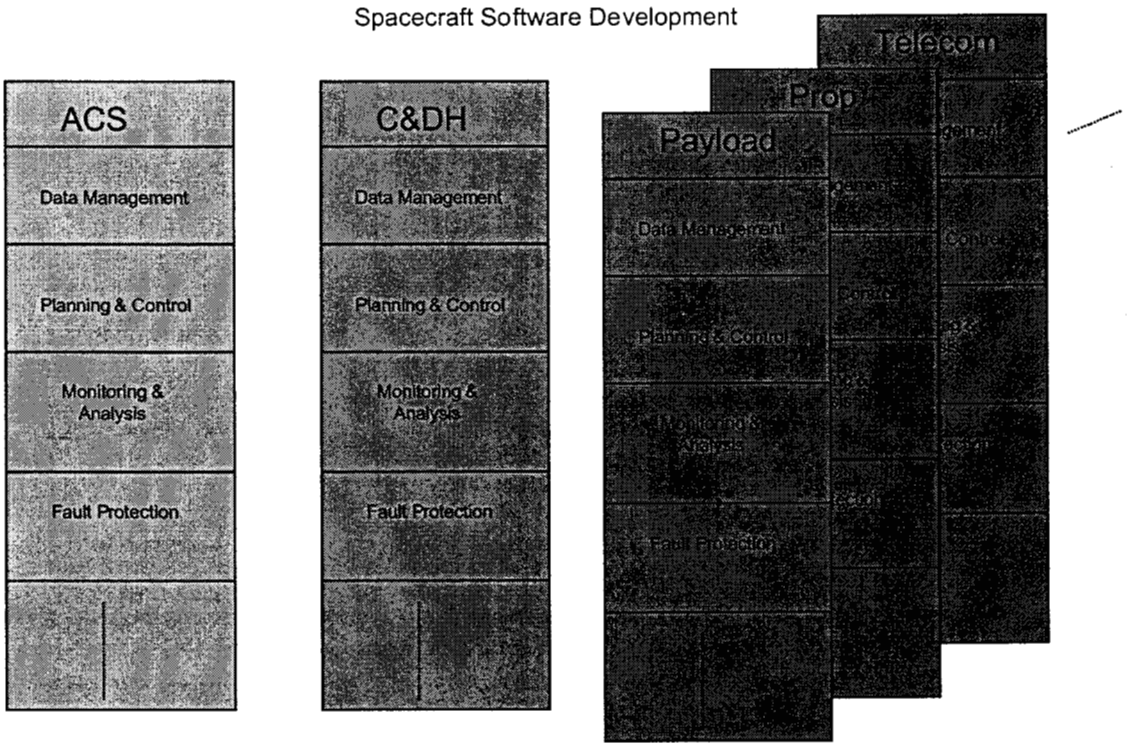
X2000 Organization



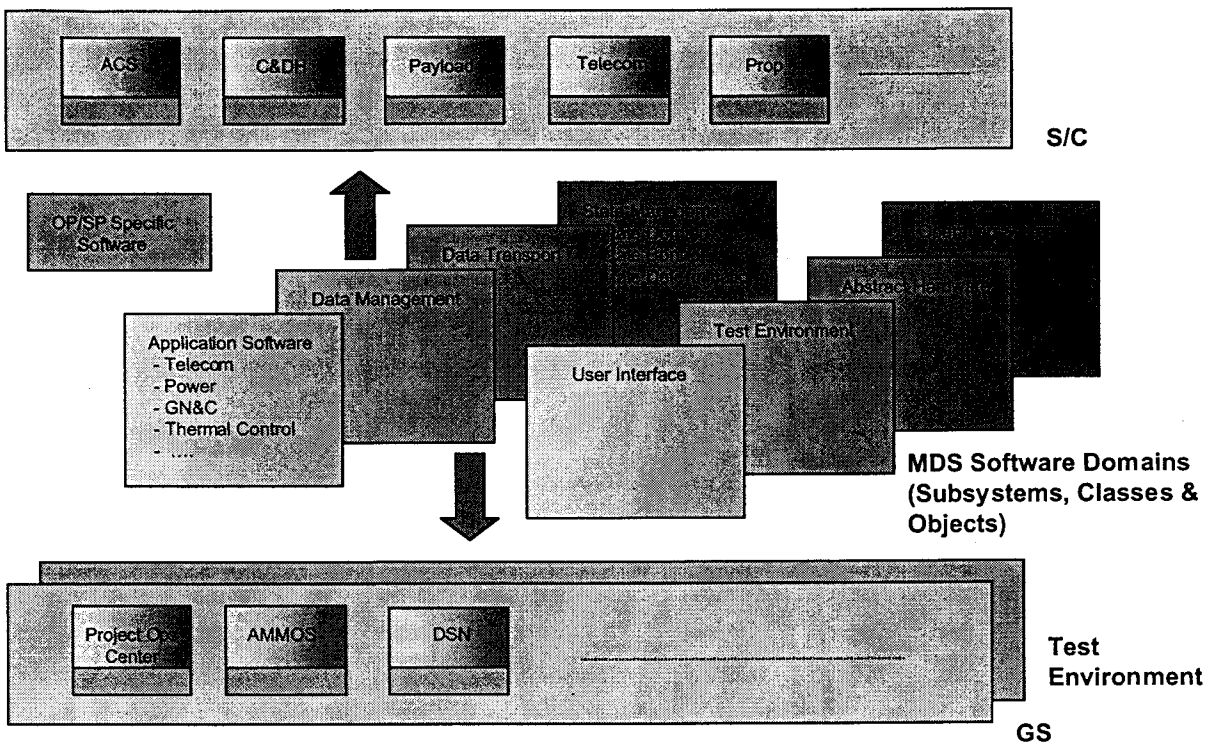
System Architecture (Mission Software System)

- All 3 missions will inherit mission software currently under development by the Mission Data System Project:
  - MDS is a unified flight, ground and test software system
  - MDS has state based, goal oriented architecture
  - MDS is integrated with existing portions of TMOD external to MDS
  - MDS designed to be easily adapted, extended by users
- All 3 missions will adapt MDS software and add mission unique software
  - Adapted and new software will conform to MDS supplied software architectural framework
  - OP/SP software development will be according to OP/SP Software Management Plan: plan is an adaptation of MDS SMP
- All 3 missions will use software tools and development environment supplied by MDS

Old S/C Software Development Approach



OP/SP Mission Software Architecture



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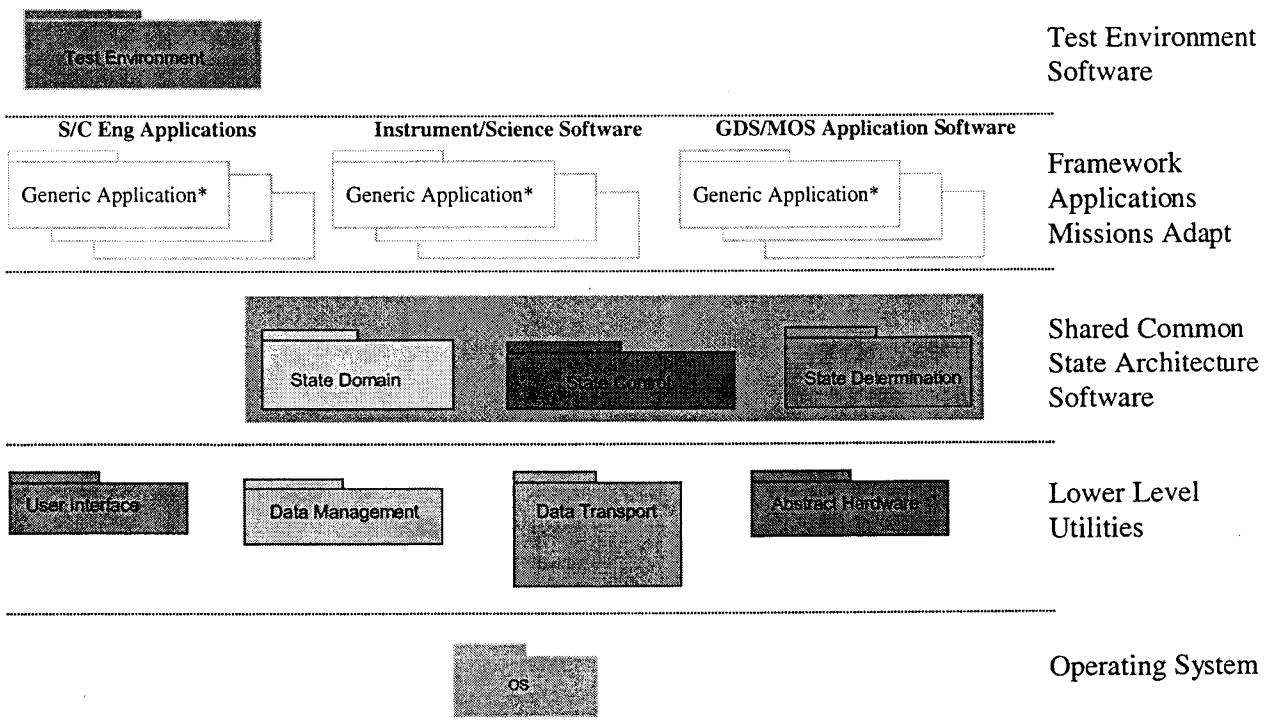
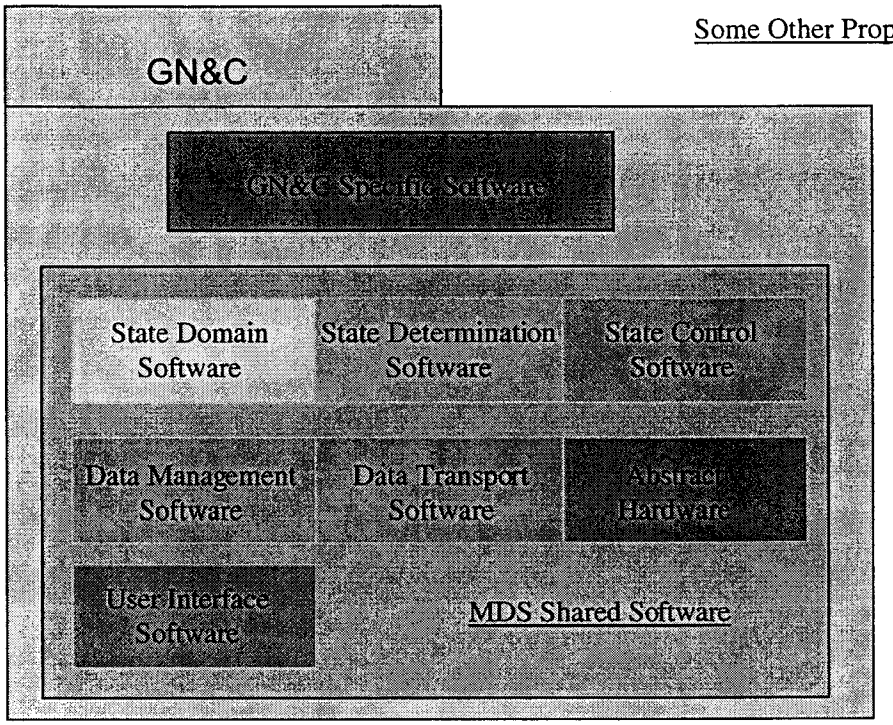
MDS Software System



*Applications frameworks that MDS develops

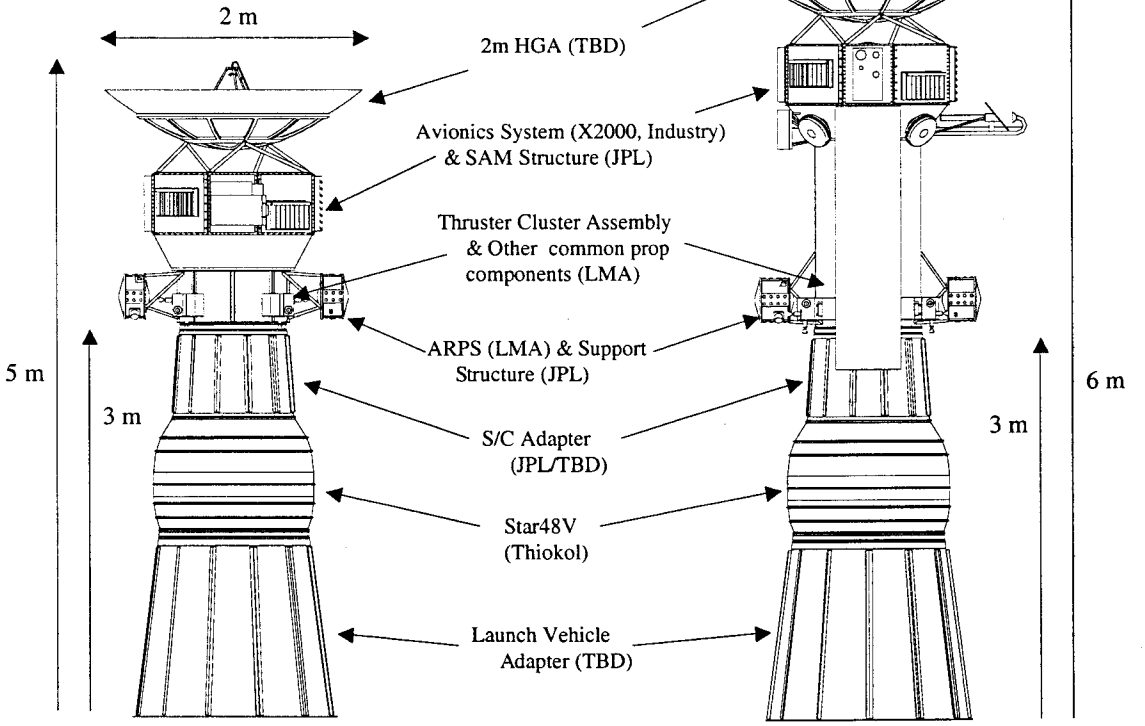
Some Generic Application Subsystems



Some Other Proposed Generic Applications

- Telecom
- Misc Data Products
- Power
- Science Data Processing
- Mass Storage
- Generic Science Instrument
- Thermal Cntl
- Bus Bandwidth
- Pyro And Misc Devices

OPSP Commonality

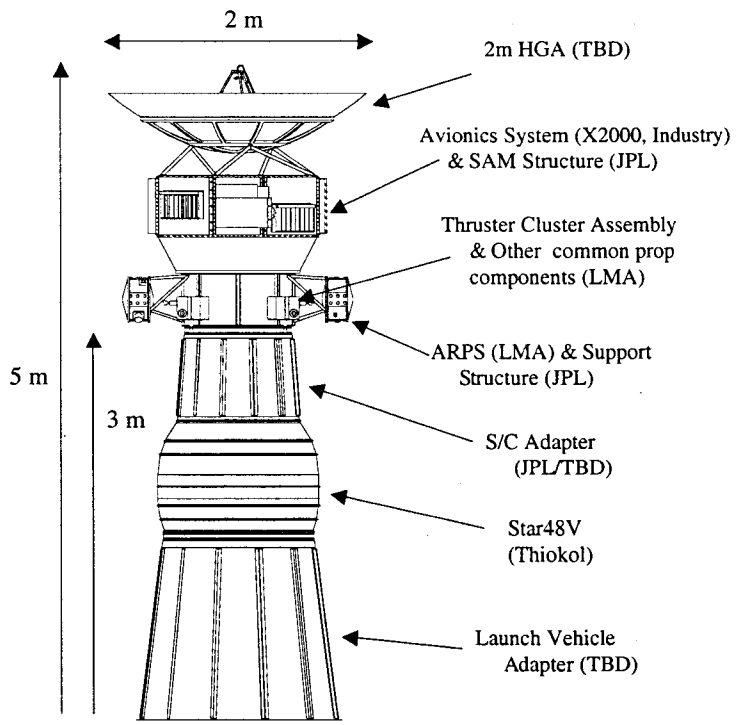


Pluto-Kuiper Express

Europa Orbiter

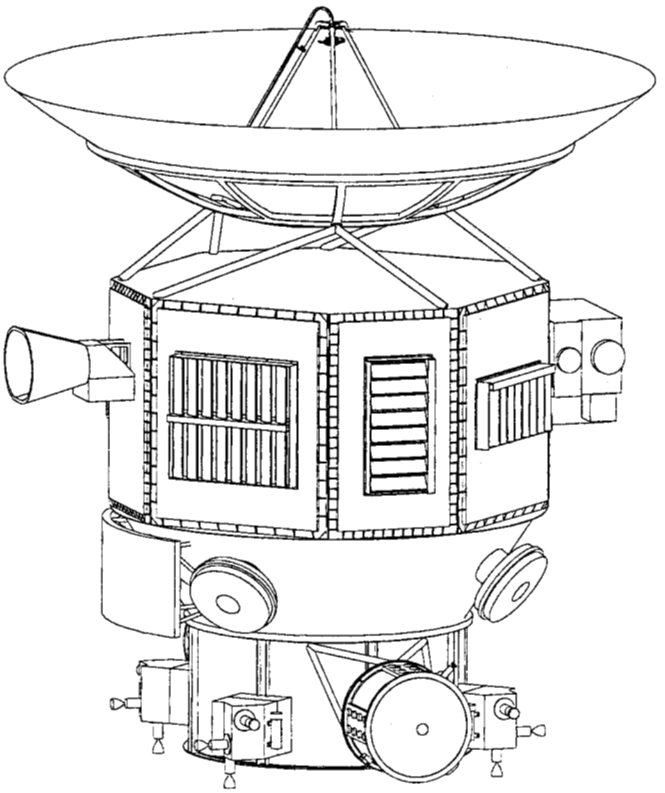
Major Design Deltas from Europa Orbiter

- Monoprop propulsion system
- No reaction wheels
- Data mining
- On-board Navigation



Pluto Kuiper Express Configuration

Pluto Kuiper Express Operational Configuration

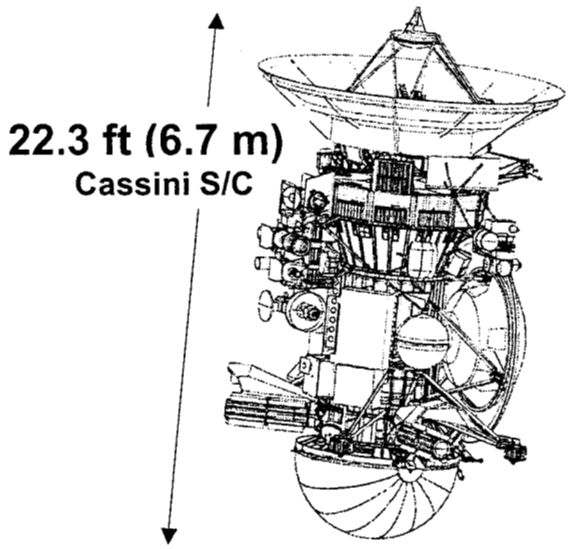


Flight System - OP/SP Hardware

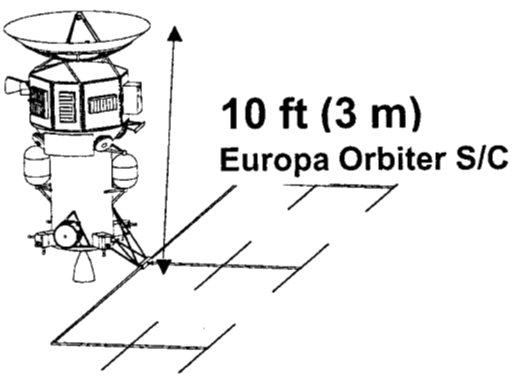
- Other hardware being developed by the OP/SP Project that will be used on multiple missions:
  - Power Sources
    - RPS (all 3), if utilized
    - Battery (all 3)
  - Telecom Subsystem
    - Antennas (E & PKE)
    - Electronics (all 3)
  - Attitude Sensors
    - Star tracker (all 3)
    - Inertial Measurement Unit (all 3)
    - Sun Sensor (E & PKE)
    - Interface Electronics (all 3)
  - Propulsion
    - Thruster Clusters (E & PKE)
  - Mechanical Structure (E & PKE)
    - Adapter to Star 48V
    - Adapter between Star 48V & Upper Stage
    - Electronics Bus
    - Miscellaneous Secondary Structure (Brackets, Supports, etc.)

Flight System - OP/SP Hardware

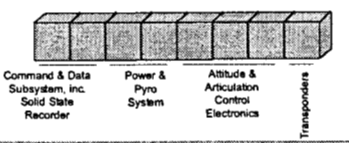
- Europa mission-unique hardware:
  - Instruments
  - Propulsion module
  - Reaction wheels
  - Thermal blankets (some)
  - Cabling (some)
- Pluto mission-unique hardware:
  - Instruments
  - Propulsion module
  - Thermal blankets (some)
  - Cabling (some)
- Solar Probe mission-unique hardware:
  - Instruments
  - Propulsion module
  - High gain antenna/heat shield
  - Structure
  - Thermal blankets
  - Cabling



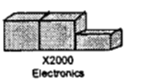
Modern long-life, highly-reliable spacecraft: X2000 contribution



Cassini Bays



X2000 Chassis



	CDS, inc. SSR	PPS	AACS Electronics	Transponders	Packaging/ Structure	Total	X2000 Electronics
MASS	59.2	45.4	20.9	18.3	54.1	198.0	52 kg
POWER	69.0	36.7	31.4	17.3	0.0	154.4	85 W
VOLUME	0.072	0.072	0.108	0.036	N/A	0.288	0.074

Shielded Solid-State Recorders
Orbit insertion
cubic meters

I&T Approach

- X2000 First Delivery Project Integrates Europa Orbiter EM and Flight avionics
- OP/SP takes delivery of EO avionics and begins System Test and Launch Operations (STLO)
- X2000/OP/SP procures and integrates PKE EM and flight avionics
- Multiple testbeds (at least 2) will be maintained for first integration of hardware and software
  - Most likely comprised of engineering model hardware
- EO and PKE flight engineering systems built up together until mission unique items are integrated (propulsion, instruments)

PKE/EO Concurrent Integration